REVIEW OF NOMENCLATURE OF KEWEENAWAN IGNEOUS ROCKS[1]

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The Keweenawan igneous rocks of the Lake Superior region have been studied and discussed by many geologists during the past thirty years. At the beginning of that period microscopical petrography was in its infancy, and minor errors due to faulty methods inevitably resulted. In the course of the years these have been gradually corrected, involving changes of nomenclature. Some variations in nomenclature have resulted from the varying points of views of the authors. But the general progress of petrography has brought more numerous and important modifications.

In order to make the names used by the prominent writers on the subject more readily intelligible, a correlation of these is presented herewith. It must be remembered that, since the basis of petrographic classification used by the authors has varied somewhat, such a correlation can be only an approximation, but it will nevertheless serve the purpose of showing the various changes that have occurred, and of presenting, at least in its outlines, the main facts of nomenclature of each writer.

In order to give precision to such a correlation, it is desirable that the nomenclature of each writer be compared, not simply with that used by other authors, but also with an expressed and definite classification. Therefore the following classification has been prepared, on the basis of textures and mineral composition. It is not a general classification of igneous rocks, but is intended to include merely the types represented in the Keweenawan of the Lake Superior region.

Macfarlane,[2] in 1866, described the Keweenawan rocks of Michipicoten Island. He found melaphyre, trap, amygdaloid, quartz porphyry, porphyrite, and trachytic phonolite. His "quartz porphyry,"

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Thos. Macfarlane, *Geol. Surv. of Canada, 1863–66*, 1866.

which occurred at the contact of the sandstone and trap, was doubtless a modified quartzite. His "trachytic phonolite" is not fully described, and correlation is uncertain.

J. H. Kloos,[1] in 1871, described gabbro or hypersthenite, black porphyry or melaphyre, porphyry and amygdaloid. The first named was probably a gabbro and the second a diabase.

Pumpelly,[2] in 1873, described melaphyre, trap, and amygdaloid without microscopic study; he distinguished three kinds of melaphyre, coarse-grained, fine-grained, and melaphyre porphyry. Correlations of these names are impracticable, and would be misleading rather than helpful.

Marvine,[3] in the same year, described melaphyre, trap, diorite, and amygdaloid. Pumpelly later claimed, probably correctly, that Marvine's diorite included samples of diabase, melaphyre, and gabbro but no true diorite.

Streng,[4] in 1877, described melaphyre, melaphyre porphyry, and hornblende gabbro from the Keweenawan of Minnesota. He published chemical analyses of two of these which permit their correlation on the quantitative basis (see Table III).

Pumpelly,[5] in 1878, described the alterations which some of the Keweenawan rocks had suffered in great detail, but brought to light no additional varieties of the unaltered rocks.

The same author,[6] in 1880, identified eight or ten kinds of igneous rocks in the Keweenawan (see the correlation table). He distinguished diallage from augite by means of the parting in the former, and, in accordance with the usage at that time, called a massive igneous rock containing plagioclase and diallage a gabbro, while one containing plagioclase and augite he called a diabase. But in his descriptions and illustrations, his diabase seems to have an ophitic texture in all cases. His identifications of the various plagioclase feldspars were all based on incorrect methods, so that his so-called

[1] J. H. Kloos, *Zeitschrift der deutschen geologischen Gesellschaft*, p. 417, 1871.

[2] R. Pumpelly, *Geol. of Mich.*, Vol. I, Pt. 2, 1873.

[3] A. R. Marvine, *ibid.*

[4] A. Streng, *N. J. Min. Geol.*, 1877.

[5] R. Pumpelly, *Proc. Amer. Acad.*, Vol. XIII, p. 285, 1878.

[6] R. Pumpelly, *Geol. Wis.*, Vol. III, pp. 27–49, 1880.

Textures	Chief feldspar orthoclase			Orthoclase with plagioclase
	+ Quartz		− Quartz	
	± Mica ± Amphibole ± Pyroxene			
	± Microcline	+ Anorthoclase	± Microcline	
Granitic	Granite	Soda granite	Syenite	Monzonite
Ophitic				
Porphyritic (Phenocrysts prominent)	Rhyolite Porphyry (Quartz porphyry)	Quartz Keratophyre	Trachyte Porphyry	
Felsitic or Porphyritic (Phenocrysts few)	Rhyolite	Quartz Keratophyre	Trachyte	
Fragmental	Acid tuffs			
Glassy	Obsidian			

TABLE I.—Mineralogical Classification of Keweenawan Igneous Roc

equal					
	With quartz				
	+Monoclinic pyroxene		+Orthorhombic Pyroxene	+Amphibole ±Biotite	No ferro-magnes mineral
	+Orthoclase	−Orthoclase			
	Orthoclase Gabbro	Quartz Gabbro	Quartz Norite	Quartz Diorite	Plagioclasite
	Orthoclase Diabase	Quartz Diabase	Quartz Enstatite diabase		
				Dacite	

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	Orthoclase Diabase	Quartz Diabase	Quartz Enstatite diabase		
				Dacite	

				No feldspar	
+ Orthorhombic Pyroxene			+ Olivine	± Pyroxene ± Amphibole ± Biotite	
noclinic Pyroxene	− Olivine	+ Olivine		− Olivine	+ Olivine
Augite Norite	Norite	Olivine Norite	Troctolite	Pyroxenite	Peridotite
Hypersthene Diabase					
Basalt Tuffs					
Tachylyte					

albite and oligoclase are actually andesine-oligoclase, his labradorite is andesine, and his anorthite is chiefly labradorite with some bytownite.

Irving[1] followed the practice of Pumpelly, but described about twice as many petrographic varieties. He protested against the practice of basing rock names on any such distinction as that between diallage and augite, but followed the custom, nevertheless, in the main, although he tried to discriminate between diabase and gabbro on the basis of coarseness of crystallization, assigning the name gabbro to the coarser grained varieties. Irving's orthoclase gabbro has been called hornblende gabbro by Wadsworth, and porphyritic gabbro by N. H. Winchell; it is nearly the same as Lane's gabbro aplite; recently it has been called oligoclase gabbro by F. E. Wright.[2]

N. H. Winchell,[3] in 1881, described thin sections of dolerite, labradorite rock, hyperite, and gabbro. He made the name "dolerite" so general in meaning as to include gabbro, diabase, olivine gabbro, olivine diabase, augite andesite, and basalt. His "labradorite rock" was called "anorthite rock" by Irving, and is now called plagioclasite (or anorthosite), while his hyperite is now known as norite.

Wadsworth,[4] in 1887, proposed a new classification of the Keweenawan igneous rocks on the basis of the alterations which a given type has undergone. Thus, a gabbro whose augite had altered to hornblende he would call a gabbro, diorite. A peridotite may by alteration become a serpentine or a talc schist; in either case Wadsworth would call it still a peridotite, adding a name to indicate its present condition. Consequently, a rock called, for example, a gabbro by Wadsworth, may belong to any one of a dozen types as commonly recognized. Nevertheless, Wadsworth's names as actually applied in this case may be correlated approximately with the names of other writers, as shown in the table.

Wadsworth indorsed Irving's protest against using the distinction

[1] R. D. Irving, *Geol. Wis.*, Vol. III, pp. 167–206, 1880; *Mon.* V. *U. S. G. S.*, 1883, and *Geol. Wis.*, Vol. I, p. 340, 1883.

[2] F. E. Wright, *Science*, Vol. XXVII, p. 892, June, 1908.

[3] N. H. Winchell, *Proc. A. A. A. S.*, Vol. XXX, p. 160, 1881.

[4] M. E. Wadsworth, *G N. H. S. Minn.*, Bull. 2, 1887.

between augite and diallage as a basis of rock classification, and yet, like Irving, he used it. He did not discriminate sharply between the ophitic and the poikilitic textures, both of which may be found, sometimes together, in Minnesota diabases.

Bayley,[1] in 1889–97, described the gabbro bathylith of Minnesota in considerable detail, and also studied the peripheral phases of the gabbro. To emphasize the close connection in origin between the peridotite and the gabbro of the district, he called the former nonfeldspathic gabbro. Although some of the peripheral phases described by Bayley may be of later date than the gabbro, if we assume that they all belong in the Keweenawan, we find that Bayley recognizes not only augite syenite of Irving, but also a porphyritic equivalent which he calls quartz keratophyre on account of the presence of anorthoclase. He speaks of olivine pyroxene aggregates which should apparently be correlated with wehrlite, dunite, and pyroxenite.

In the peripheral phases he finds a texture which he considers somewhat characteristic; it consists of the presence of many rounded grains of the more important constituents inclosed by other minerals. Bayley calls it the granulitic texture. It has been called the contact structure by Salomon, and the globular by Fouqué. It is well described by the term globular or globulitic.

Grant,[2] in 1893 and 1894, described gabbro, diabase, granite, and fine-grained rocks previously called muscovadites in the Minnesota reports. Grant's granite is the equivalent of Irving's augite syenite, later called soda augite granite by Bayley (see the correlation table). The fine-grained rocks, called muscovadites, include border facies of the gabbro mass of various types, but especially norite, fine grained gabbro often with hypersthene, olivine norite, cordierite norite, etc.

Hubbard,[3] in 1898, described various types of the Keweenawan of Keweenaw Point. His melaphyre is chiefly andesite or basalt;

[1] W. S. Bayley, *Am. J. Sc.*, Vol. XXXVII, p. 54, 1889; Vol. XXXIX, p. 273, 1890; *U. S. G. S.*, Bull. 109, 1893; *J. G.*, Vol. I, p. 433, 1893; Vol. II, p. 814, 1894; Vol. III, p. 1, 1895; *U. S. G. S.*, Mon. 28, p. 519, 1897.

[2] U. S. Grant, *G. N. H. S. Minn.*, 21st Ann. Rep., p. 5, 1893; 22d Ann Rep., p. 76, 1894.

[3] L. L. Hubbard, *Geol. Surv. Mich.*, Vol. VI, Pt. 2, 1898.

TABLE II

CORRELATION OF NOMENCLATURES OF KEWEENAWAN

R. Pumpelly 1880	R. D. Irving 1880–1883	M. E. Wadsworth 1887–1893	W. S. Bayley 1889–1897	L. L. Hubbard 1898	
	Granite				
Quartz porphyry	Quartz porphyry			Porphyry	Quartz
				Felsite	1 Felsit 2 Felso 3 Ortho
	1 Augite syenite 2 Granitell		1 Granite 2 Soda augite granite		1 Augit 2 Gran 3 Augit 4 Gabb
	Granitic porphyry		Quartz keratophyre		
	Quartzless porphyry				Quartzl
Felsite porphyry	1 Felsite? 2 Felsitic porphyry			Felsite	1 Felsit 2 Ortho
		Quartz biotite diorite			
1 Augite diorite 2 Melaphyre	1 Hornblende gabbro 2 Orthoclase gabbro	Altered gabbro	Hornblendic gabbro		Gabbro
	Orthoclase diabase				
			Quartz diabase		1 Quart 2 Diaba
					Enstatit
		1 Gabbro? 2 Quartz diorite	Quartz diorite		
					Quartz
	Anorthite rock				
	Diorite?				
	Quartzless porphyry			Doleritic melaphyre	
	Diabase porphyrite	1 Augite Andesite 2 Hornblende porphyrite		1 Felsite porphyrite 2 Melaphyre	1 Felsit 2 Felso
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro			Doleritic melaphyre	
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro	Diabase	Diabase	Diabasic melaphyre	Diabase
Porphyritic diabase	Diabase porphyrite				1 Porph 2 Labra
	1 "Ashbed" diabase 2 Diabase porphyrite		Porphyrite	Porphyrite	Augite a
	1 Olivine diabase 2 Olivine gabbro		Olivine gabbro		
1 Chrysolitic diabase 2 Melaphyre	1 Olivine diabase 2 Olivine gabbro 3 Melaphyre	1 Diabase 2 Granophyrite	1 Olivine diabase 2 Olivine gabbro	Ophitic melaphyre	1 Melap 2 Melap 3 Olivin
	Diabase porphyrite			Doleritic melaphyre	Melaphy
"Ashbed" Diabase	1 Diabase porphyrite 2 Melaphyre	1 Basalt 2 Melaphyre		Melaphyre	1 Felsit 2 Melap 3 Labra

TABLE II

OF NOMENCLATURES OF KEWEENAWAN IGNEOUS ROCKS

	L. L. Hubbard 1898	A. C. Lane 1898–1906	A. N. Winchell 1900	N. H. Winchell and U. S. Grant 1900	Mineralogical Classification
				Granite	Granite
	Porphyry	Quartz porphyry		Quartz porphyry	Rhyolite porphyry
	Felsite	1 Felsite 2 Felsophyre 3 Orthophyre		Rhyolite	Rhyolite
				Tuff	Acid tuffs
				Obsidian and apobsidian	Obsidian
ite		1 Augite-porphyrite ? 2 Granophyre 3 Augite syenite 4 Gabbro aplite		1 Granite 2 Soda granite	Soda granite
				Quartz keratophyre	Quartz keratophyre
				Syenite ?	Syenite
		Quartzless porphyry			Trachyte porphyry
	Felsite	1 Felsite 2 Orthophyre		Trachyte	Trachyte
				Syenite or Granophyre	Monzonite
		Gabbro aplite ?	Orthoclase gabbro	Porphyritic gabbro	Orthoclase gabbro
					Orthoclase diabase
			Quartz gabbro	Quartz gabbro	Quartz gabbro
		1 Quartz diabase 2 Diabase granophyrite		Diabase	Quartz diabase
				Quartz norite	Quartz norite
		Enstatite diabase		Diabase with hypersthene	Quartz enstatite diabase
				Quartz diorite	Quartz diorite
		Quartz porphyrite			Dacite
			Plagioclasite	Anorthosite	Plagioclasite
				1 Diorite 2 Gabbro	Diorite
	Doleritic melaphyre			Porphyrite	Andesite Porphyry
	1 Felsite porphyrite 2 Melaphyre	1 Felsite porphyrite 2 Felsophyrite		Andesite	Andesite
	Doleritic melaphyre		Gabbro	1 Gabbro 2 Diabase	Gabbro
	Diabasic melaphyre	Diabase (in dikes)	Diabase	Diabase	Diabase
		1 Porphyrite 2 Labradorite porphyrite		1 Diorite porphyrite 2 Diabase porphyrite	Augite andesite porphyry
	Porphyrite	Augite andesite		Basalt	Augite andesite
			Olivine gabbro	Olivine gabbro	Olivine gabbro
	Ophitic melaphyre	1 Melaphyre ophite 2 Melaphyre porphyrite 3 Olivine diabase (in dikes)	Olivine diabase	Diabase with olivine	Olivine diabase
	Doleritic melaphyre	Melaphyre dolerite		Porphyritic basalt or zirkelite	Basalt porphyry
	Melaphyre	1 Felsite 2 Melaphyre porphyrite 3 Labradorite porphyrite	Basalt	Basalt	Basalt
				Tuff or zirkelite	Basalt tuffs
				Zirkelite	Tachylyte

	1 Augite syenite 2 Granitell		1 Granite 2 Soda augite granite		1 Augit 2 Gran 3 Augit 4 Gabb
	Granitic porphyry		Quartz keratophyre		
	Quartzless porphyry				Quartzl
Felsite porphyry	1 Felsite? 2 Felsitic porphyry			Felsite	1 Felsit 2 Ortho
		Quartz biotite diorite			
1 Augite diorite 2 Melaphyre	1 Hornblende gabbro 2 Orthoclase gabbro	Altered gabbro	Hornblendic gabbro		Gabbro
	Orthoclase diabase				
			Quartz diabase		1 Quart 2 Diaba
					Enstatit
		1 Gabbro? 2 Quartz diorite	Quartz diorite		
					Quartz
	Anorthite rock				
	Diorite?				
	Quartzless porphyry			Doleritic melaphyre	
	Diabase porphyrite	1 Augite Andesite 2 Hornblende porphyrite		1 Felsite porphyrite 2 Melaphyre	1 Felsit 2 Felso
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro			Doleritic melaphyre	
1 Diabase 2 Gabbro	1 Diabase 2 Gabbro	Diabase	Diabase	Diabasic melaphyre	Diabase
Porphyritic diabase	Diabase porphyrite				1 Porph 2 Labra
	1 "Ashbed" diabase 2 Diabase porphyrite		Porphyrite	Porphyrite	Augite a
	1 Olivine diabase 2 Olivine gabbro		Olivine gabbro		
1 Chrysolitic diabase 2 Melaphyre	1 Olivine diabase 2 Olivine gabbro 3 Melaphyre	1 Diabase 2 Granophyrite	1 Olivine diabase 2 Olivine gabbro	Ophitic melaphyre	1 Melap 2 Melap 3 Olivin
	Diabase porphyrite			Doleritic melaphyre	Melaphy
"Ashbed" Diabase	1 Diabase porphyrite 2 Melaphyre	1 Basalt 2 Melaphyre		Melaphyre	1 Felsite 2 Melap 3 Labra
			Hypersthene gabbro		
	Norite				
					Enstatite
		1 Forellenstein 2 Troctolite			Troctolit
			Granulitic pyroxene rock		
			Nonfeldspathic gabbro		

				Tuff	Acid tuffs
				Obsidian and apobsidian	Obsidian
ite		1 Augite-porphyrite ? 2 Granophyre 3 Augite syenite 4 Gabbro aplite		1 Granite 2 Soda granite	Soda granite
				Quartz keratophyre	Quartz keratophyre
				Syenite ?	Syenite
		Quartzless porphyry			Trachyte porphyry
	Felsite	1 Felsite 2 Orthophyre		Trachyte	Trachyte
				Syenite or Granophyre	Monzonite
o		Gabbro aplite ?	Orthoclase gabbro	Porphyritic gabbro	Orthoclase gabbro
					Orthoclase diabase
			Quartz gabbro	Quartz gabbro	Quartz gabbro
		1 Quartz diabase 2 Diabase granophyrite		Diabase	Quartz diabase
				Quartz norite	Quartz norite
		Enstatite diabase		Diabase with hypersthene	Quartz enstatite diabase
				Quartz diorite	Quartz diorite
		Quartz porphyrite			Dacite
			Plagioclasite	Anorthosite	Plagioclasite
				1 Diorite 2 Gabbro	Diorite
	Doleritic melaphyre			Porphyrite	Andesite Porphyry
	1 Felsite porphyrite 2 Melaphyre	1 Felsite porphyrite 2 Felsophyrite		Andesite	Andesite
	Doleritic melaphyre		Gabbro	1 Gabbro 2 Diabase	Gabbro
	Diabasic melaphyre	Diabase (in dikes)	Diabase	Diabase	Diabase
		1 Porphyrite 2 Labradorite porphyrite		1 Diorite porphyrite 2 Diabase porphyrite	Augite andesite porphyry
	Porphyrite	Augite andesite		Basalt	Augite andesite
			Olivine gabbro	Olivine gabbro	Olivine gabbro
	Ophitic melaphyre	1 Melaphyre ophite 2 Melaphyre porphyrite 3 Olivine diabase (in dikes)	Olivine diabase	Diabase with olivine	Olivine diabase
	Doleritic melaphyre	Melaphyre dolerite		Porphyritic basalt or zirkelite	Basalt porphyry
	Melaphyre	1 Felsite 2 Melaphyre porphyrite 3 Labradorite porphyrite	Basalt	Basalt	Basalt
				Tuff or zirkelite	Basalt tuffs
				Zirkelite	Tachylyte
o				Hypersthene gabbro	Augite norite
				Norite (muscovadite)	Norite
		Enstatite diabase		Hypersthene diabase	Hypersthene diabase
				Norite with olivine	Olivine norite
		Troctolite	Troctolite	Forellenstein or troctolite	Troctolite
rock				Pyroxenite	Pyroxenite
ro			Peridotite	Peridotite	Peridotite

his doleritic melaphyre is a coarser basalt, or a gabbro; his ophitic melaphyre is a poikilitic and luster-mottled diabase; and his porphyrite is chiefly andesite and trachyte.

Lane,[1] in 1898–1906, described the Keweenawan rocks of Isle Royale and northern Michigan. His melaphyre porphyrite is the equivalent of Pumpelly's "Ashbed" diabase and Irving's diabase porphyrite, Lane's melaphyre ophite is an olivine diabase, luster-mottled by means of poikilitic textures; his doleritic melaphyre is a basalt porphyry. Lane would confine the name diabase to dike rocks. His augite syenite is said to be at least in part an equivalent of Bayley's quartz diabase. He uses the term "ophitic" in a narrow sense, not justified by the original definition of Michel Lévy,[2] nor by his usage.[3] He applies it to those luster-mottled rocks in which single pyroxene individuals inclose several plagioclase crystals, usually lath-shaped and irregularly placed. It is, thus, for Lane, a variety of the poikilitic texture. In its original meaning, still commonly used by many, and adopted here, it refers to that texture of a basic igneous rock produced when the plagioclase crystallizes in lath-shaped forms before the pyroxene solidifies.

A. N. Winchell,[4] in 1900, described in detail a few samples of the Keweenawan rocks of Minnesota. He used the new term plagioclasite for the rocks previously known usually as anorthosites.

N. H. Winchell and U. S. Grant[5] published in 1900 by far the most complete accounts of the petrography of the Keweenawan igneous rocks. Their nomenclature varies very little from that commonly in use at present. They described practically all the petrographic types of the Keweenawan previously known and added some half dozen new varieties. They used diorite porphyrite or diabase porphyrite to designate more or less ophitic types of andesite porphyry or augite andesite porphyry. They used Wadsworth's

[1] A. C. Lane, *Geol. Surv. Mich.*, Vol. VI, Pt. 1, 1898; *Geol. Soc. Amer.*, Bull., Vol. XIV, pp. 369, 385, 1903; *J. G.*, Vol. XII, p. 83, 1904; *Geol. Surv. Mich.*, Ann. Rep., 1903, pp. 205, 239, 1905; *Ceol. Surv. Mich.*, Ann. Rep., 1904, p. 113, 1905; *Proc. L. Sup. Mg. Inst.*, Vol. XII, p. 85, 1906.

[2] *Bull. Soc. Geol. Fr.*, Vol. VI, 1878, p. 158.

[3] *Minéralogie micrographique*, 1879, Pl. XXXVI. See also p. 153.

[4] A. N. Winchell, *Amer. Geol.*, Vol. XXVI, pp. 151 (197), 261, 348 (1900).

[5] N. H. Winchell and U. S. Grant, *G. N. H. S. Minn.*, Fin. Rep., Vol. V, 1900.

name zirkelite for a devitrified basalt, basaltic tuff, or tachylyte; devitrified obsidian they called an apobsidian, and a devitrified rhyolite an aporhyolite, as suggested by Bascom. Wadsworth's quartz biotite diorite is called syenite by Grant. It is an intermediate type corresponding to a monzonite.

The quantitative classification of igneous rocks as proposed by Cross, Iddings, Pirsson, and Washington may be used as the basis of a correlation of the Keweenawan igneous rocks. From a chemical point of view such a correlation (see Table III) is more exact than one based upon the mineral composition and texture, but it can include only those rock types of which satisfactory quantitative analyses are available.

An examination of the table of correlation on this basis will reveal the fact that the number of satisfactory analyses available is not great, especially when compared with the descriptions previously mentioned. Several of the early analyses are not included in the tabulation because of manifest inaccuracy or incompleteness.

The analyses of Streng and Pumpelly are good for the time at which they were made. The norm of Pumpelly's andose is: or 7.78, ab 42.44, an 17.24, hy 1.30, ol 17.97, mt 4.41, il 4.41. The norm of his camptonose is: or 7.23, ab 22.01, an 23.91, ne 4.26, di 22.55, ol 7.47, mt 4.18, il 5.32. The norm of his auvergnose is: or 0.56, ab 16.24, an 36.97, di 15.88, hy 20.34, ol 1.11, mt 3.71, il 1.98. Sweet published two analyses of Keweenawan rocks; the one of diabase from the Ashland mine, Ashland Co., Wis., is wholly unsatisfactory; the other is approximately correct, and classifies as hessose. The analyses of gabbros published by Wadsworth are recalculated in Washington's tables[1] of chemical analyses of igneous rocks; the norm of his diabase granophyrite from the Cleveland mine is: Q 5.10, or 8.34, ab 16.77, an 32.25, di 11.02, hy 9.90, mt 8.45, il 5.17; the norm of his sample from Houghton Co. is: Q 8.46, or 8.90, ab 23.06, an 16.40, di 13.75, hy 20.82, mt 5.80, ap 0.34. Washington's tables give full details regarding the recalculation of the analyses of Keweenawan rocks published by Van Hise, N. H. Winchell, and Bayley. The norms of the analyses reported by Hubbard may be summarized as follows:

[1] H. S. Washington, *U. S. G. S.*, P. P. 14, 1903.

[1] A. Streng 1877	[2] R. Pumpelly 1878	[3] E. T. Sweet 1880	[4–5] M. E. Wadsworth 1887–1893	[6] C. R. Van Hise 1892	[7] N. H. Winche 1893
			Gabbro (4)? Pigeon Pt., Minn.		
Hornblende gabbro Duluth, Minn.	Melaphyre Middle of bed 87 Eagle River section, Mich.				
Melaphyre porphyry Duluth, Minn.			Gabbro (4) Baptism River, Minn.		
		Diabase Fond du Lac Mine, Douglas Co., Wis.	Diabase granophyrite (5) Cleveland Mine, Keweenaw Pt., Mich.		
			Diabase granophyrite (5) Sec. 2, T. 49 N. R. 27 W. Houghton Co., Mich.		
	Melaphyre Bottom of bed 87, Eagle River section, Keweenaw Pt., Mich.				
	Melaphyre Lower part Bed 64, Eagle River section, Keweenaw Pt., Mich.			Diabase Sec. 13, T. 47 N. R. 46 W. Gogebic Co., Mich.	Gabbro (gran Bashitanaq Lake, Minn

TABLE III

F KEWEENAWAN IGNEOUS ROCKS OF THE LAKE SUPERIOR REGION

ell	8–11 W. S. Bayley 1889–1895	12 A. C. Lane 1898	13–16 L. L. Hubbard 1898	17–18 A. N. Winchell 1900–1908	19–21 A. C. Lane 1905–1906	Quantit
			Felsite (13) Keweenaw Pt., Mich.			I. 3. 1. Magde
			Felsite (14) (No. 17193A) Keweenaw Pt., Mich.			I. 3. 2. Teham
			Felsite (14) (No. 16951) Keweenaw Pt., Mich.			I. 4. 1. Lebach
	Granite (8) Pigeon Pt., Minn. Soda granite (9) Pigeon Pt., Minn. Quartz keratophyre (8) Pigeon Pt., Minn.					I. 4. 1. Liparo
	Quartz keratophyre (9) Pigeon Pt., Minn.					I. 4. 2. Toscan
				Plagioclasite (17) Carlton Peak, Minn.		I. 5. 4. Labrad
	Quartz diorite (9) Pigeon Pt., Minn.					II. 4. 2 Adame
					Gabbro-aplite (19) Mt. Bohemia, Mich.	II. 4. 3 Tonalc
			Felsite porphyrite (15) Keweenaw Pt., Mich.			II. 5. 1 Umpte
			Porphyrite (16) Keweenaw Pt., Mich.			II. 5. 2 Akeros
		Porphyrite (V and VI) Isle Royale, Mich.		Orthoclase gabbro (17) Duluth, Minn.		II. 5. 3 Andose
						II. 5. 3 Beerba
				Quartz gabbro (17) Little Saganaga Lake, Minn.		II. 4–5 Placer
		Porphyrite (I) Isle Royale, Mich.				II. 5. 3 Beerba
	Olivine gabbro (9) Pigeon Pt., Minn. Olivine gabbro (10) T. 61 N. R. 12 W., Minn.	Porphyrite (IV) Ophite (VII) Isle Royale, Mich.		Olivine gabbro (17) Birch Lake, Minn. Diabase (17) Birch Lake, Minn.		II. 5. 4 Hessos
						III. 4. Vaalos
				"Ashbed diabase" (18) Bed 65, Eagle River section, Keweenaw Pt., Mich.		III. 5. Kilauc
				Orthoclase gabbro (17) (Basic part) Duluth, Minn.		III. 5. Campt
ular) uab n.	Olivine gabbro (10) Birch Lake, Minn. Gabbro (11) T. 64 N. R. 8 W., Minn.			Troctolite (17) Duluth, Minn. Olivine diabase (18) Bed 108, Eagle River section, Greenstone Cliff, Keweenaw Pt., Mich.	Ophite (19) Mt. Bohemia, Mich. Diabase (20) Lighthouse Pt., Mich. Ophite (21) St. Mary Land Co., Keweenaw Pt., Mich.	III. 5. Auverg
	Hypersthene gabbro (11) Gunflint Lake, Minn.					IV. 11. Cooko

	12 A. C. Lane 1898	13–16 L. L. Hubbard 1898	17–18 A. N. Winchell 1900–1908	19–21 A. C. Lane 1905–1906	Quantitative Classification
		Felsite (13) Keweenaw Pt., Mich.			I. 3. 1. 2. Magdeburgose
		Felsite (14) (No. 17193A) Keweenaw Pt., Mich.			I. 3. 2. 3. Tehamose
		Felsite (14) (No. 16951) Keweenaw Pt., Mich.			I. 4. 1. 1. Lebachose
					I. 4. 1. 3. Liparose
					I. 4. 2. 3. Toscanose
			Plagioclasite (17) Carlton Peak, Minn.		I. 5. 4. 4,5. Labradorose
					II. 4. 2. 3. Adamellose
				Gabbro-aplite (19) Mt. Bohemia, Mich.	II. 4. 3–2. 4. Tonalose-dacose
		Felsite porphyrite (15) Keweenaw Pt., Mich.			II. 5. 1. 4. Umptekose
		Porphyrite (16) Keweenaw Pt., Mich.			II. 5. 2. 4. Akerose
	Porphyrite (V and VI) Isle Royale, Mich.		Orthoclase gabbro (17) Duluth, Minn.		II. 5. 3. 4. Andose
					II. 5. 3. 5–4. Beerbachose-andose
			Quartz gabbro (17) Little Saganaga Lake, Minn.		II. 4–5. 3. 5. Placerose-beerbachose
	Porphyrite (I) Isle Royale, Mich.				II. 5. 3. 5. Beerbachose
nn.	Porphyrite (IV) Ophite (VII) Isle Royale, Mich.		Olivine gabbro (17) Birch Lake, Minn. Diabase (17) Birch Lake, Minn.		II. 5. 4. 4.5. Hessose
					III. 4. 3. 4. Vaalose
			"Ashbed diabase" (18) Bed 65, Eagle River section, Keweenaw Pt., Mich.		III. 5. 2–3. 4. Kilauose-camptonose
			Orthoclase gabbro (17) (Basic part) Duluth, Minn.		III. 5. 3. 4. Camptonose
			Troctolite (17) Duluth, Minn. Olivine diabase (18) Bed 108, Eagle River section, Greenstone Cliff, Keweenaw Pt., Mich.	Ophite (19) Mt. Bohemia, Mich. Diabase (20) Lighthouse Pt., Mich. Ophite (21) St. Mary Land Co., Keweenaw Pt., Mich.	III. 5. 4. 4, 5. Auvergnose
1)					IV. 1[1]. 1[1]. 2. Cookose

	Magdeburgose	Tehamose	Lebachose	Umptekose		Akerose
				No. 17,039	No. 17,007	
Q	38.58	48.90	18.60	1.14	.....	.....
C	1.94	.....	.....	.....	.....	.....
or	39.48	26.13	70.61	20.57	20.57	15.01
ab	16.77	18.34	0.52	57.64	57.64	48.21
an	.....	3.61	.....	1.67	.....	7.78
ne	.....	.....	.....	.....	2.27	3.69
ac	.....	.....	4.16	.....	3.70	.....
ns	.....	.....	3.66	.....	.....	.....
di	.....	0.12	1.43	5.62	0.43	5.18
hy	.....	.....	0.86	2.70	.....	.....
ol	.....	.....	.....	.....	3.22	5.32
mt	0.46	0.70	.....	6.03	5.57	8.12
hm	1.92	1.28	.....	3.04	5.92	4.00
H_2O	0.41	1.03	0.42	2.23	1.23	2.76
Total	99.56	100.11	100.27	100.64	100.55	100.07

It is to be remarked that not one of these rock types described by Hubbard corresponds chemically with any variety described by any other author. The fact suggests possible inaccuracies in Hubbard's analyses.

Lane's analyses, as well as Hubbard's were overlooked and omitted from Washington's tables. Recalculations of the analyses given by Lane yield the following norms:

	Tonalose-dacose	Andose		Beerbachose	Hessose		Auvergnose		
		No. V	No. VI		No. IV	No. VII	No. 8 Lighth. Pt.	St. M. Land Co.	Mt. Bohemia
Q	13.08	.....	.....	.....	.....	.....	.....	1.80	.....
C	1.02	.....	.....	.....	.....	.....	.....	.....	.....
or	17.79	6.12	6.12	2.78	1.67	2.78	3.89	1.67	10.01
ab	36.15	28.82	23.58	45.59	28.82	21.48	18.35	20.96	18.34
an	16.96	24.19	30.30	20.02	34.19	41.14	36.14	31.41	31.69
ne	.....	2.84	4.26	.....	.....	.....	.....	.....	.....
di	.....	3.80	18.41	1.30	10.66	10.64	13.52	12.74	1.36
hy	11.06	.....	.....	2.76	1.56	5.76	10.77	12.20	21.62
ol	.....	23.25	2.10	12.58	12.97	6.01	13.06	.....	2.08
mt	2.32	3.94	11.14	11.37	6.50	10.44	3.71	10.67	7.42
hm	.....	.....	.....	.....	.....	.....	.....	2.24	.....
il	1.98	.....	.....	.....	.....	.....	.....	4.10	4.71
ap	.....	.....	.....	.....	.....	.....	0.34	0.34	.....
cc	.....	0.90	2.30	2.00	.....	0.70	.....	1.10	.....
pr	.....	.....	.....	.....	.....	.....	0.36	0.10	.....
H_2O	.....	5.01	3.49	2.82	3.90	1.83	.....	0.67	.....
Total	100.36	98.87	101.62	101.22	100.27	100.78	100.14	100.00	97.23

Lane's gabbro aplite differs in its norm from the orthoclase gabbro of Duluth by a greater abundance of quartz, and also by a greater proportion of alkalies as compared with salic lime. His porphyrite (VI), on the contrary, belongs to the same type (andose) as the orthoclase gabbro. His porphyrite (No. 1) is a beerbachose; the others belong to the classes, hessose and auvergnose, so well represented in the Keweenawan.

The analyses published by A. N. Winchell in 1900 were recalculated by Washington with the exception of that of the troctolite, the norm of which is: or 2.22, ab 7.86, an 28.63, ne 5.11, di 5.91, ol 30.21, mt 10.67, il 4.41, MnO 0.08, H_2O 5.23.

In view of the scarcity of analyses of the typical volcanic rocks of the Keweenawan the following new analyses are of much interest. They were made by George Steiger in the laboratory of the Survey.

ANALYSES OF KEWEENAWAN DIABASE

	No. 1*	No. 2†
SO_2	47.69	50.07
Al_2O_3	16.02	12.63
Fe_2O_3	2.41	3.84
FeO	8.70	10.30
MgO	8.31	5.23
CaO	10.54	6.55
Na_2O	2.44	3.53
K_2O	none	1.90
H_2O-	0.44	0.86
H_2O+	2.04	1.96
TiO_2	1.38	2.50
ZrO_2	none	none
CO_2	none	none
P_2O_5	0.06	0.22
SO_3	none	none
S	none	none
MnO	0.26	0.42
BaO	none	0.02
SrO	none	none
Total	100.29	100.03

* Olivine diabase from Bed 108, Eagle River section, Greenstone Cliff, Keweenaw Point, Mich Sample No. 5 of Rohn's collection of Lake Superior rocks. Rock powdered to pass a 100-mesh sieve before analysis.

† "Ashbed" diabase from Bed 65, Eagle River section, Keweenaw Point, Mich. Sample No. of Rohn's collection of Lake Superior rocks. Rock powdered to pass a 100-mesh sieve before analysis, thus improving the accuracy of the figures for ferrous iron and water.

Recalculation of these analyses on the basis of the quantitative classification gives the following norms:

	1. Olivine diabase	2. Ashbed diabase
or	.....	11.12
ab	20.44	29.87
an	32.80	13.07
di	15.60	15.12
hy	15.64	15.32
ol	7.06	2.00
mt	3.48	5.57
il	2.74	4.71
ap	0.14	0.50
H_2O	2.48	2.82
Total	100.38	100.10

The olivine diabase belongs to the same class as the Birch Lake olivine gabbros, the Lighthouse Point diabase, and several others, that is, to the auvergnose type, which seems to be the dominant type of the Keweenawan, although the hessose type, which differs only in having a greater proportion of salic minerals, is also quite abundant. But the "ashbed" diabase classifies as a camptonose, very near a kilauose. It is therefore related to Irving's melaphyre of Bed 87 of the Eagle River section, and to the more basic phases of the orthoclase gabbro of Duluth.

It is to be expected that additional analyses of the Keweenawan volcanic rocks would disclose still other types, especially such as would parallel the known plutonic types. The parallelism in composition already established is quite remarkable, considering the relatively small number of analyses available. Thus, it appears that Lane's porphyrite (No. IV) and ophite (No. VII), as well as Sweet's Douglas County diabase and Wadsworth's diabase granophyrite from the Cleveland mine, are the chemical equivalents among the volcanic and dike rocks of Bayley's olivine gabbro from Pigeon Point and from T. 61 N. R. 12 W., and of A. N. Winchell's olivine gabbro and diabase from Birch Lake among the plutonic rocks. Again, Pumpelly's melaphyre from the middle of Bed 87 and Lane's porphyrite (Nos. V and VII) from Isle Royale correspond chemically with the coarse hornblende gabbro and orthoclase gabbro from Duluth. Finally, the same chemical type, viz., auvergnose, includes plutonic rocks such as Bayley's gabbro and olivine gabbro from Birch Lake, N. H. Winchell's gabbro from Bashitanaquab Lake, and A. N. Winchell's troctolite, together with volcanic or dike rocks

such as Pumpelly's melaphyre from Bed 64, Van Hise's Gogebic County diabase, and Lane's ophite from the property of the St. Mary's Land Company, and from Mt. Bohemia.

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